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A Spot Seeding Trial with Southwestern White Pine and Blue Spruce

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Following rodent reduction, 300 seed spots each of southwestern white pine and blue spruce were sown on three mixed conifer clearcuttings. Germination was abundant. Despite favorable slope aspects, absence of heavy herbaceous competition, good cold air drainage, and initial rodent reduction, very few seedlings survived to the middle of the third summer. Major known causes of death were frost heaving, predation, and burial by soil movement. Importance of these factors differed between species. Additional seeding trials should emphasize broadcast seeding.

Keywords: Seeding, rodents, frost heaving, *Pinus strobiformis*, *Picea pungens*.

Large areas of mixed conifer forest in the Southwest are occasionally deforested by fire, and small areas by fire or logging. Natural reforestation of such areas is usually very slow except where aspen root suckers take over the site.

Experience has shown that such openings can be successfully reforested with nursery-grown seedlings if careful attention is given to species selection, seed source, site preparation, and the details of proper shipping, storage, handling, and planting. But planting is relatively expensive. Seeding is much cheaper, although at present quite unreliable. Seeding in prepared spots requires much less seed than does broadcast seeding. This study examined problems and prospects of spot seeding.

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Literature Review

In a series of seeding experiments in mixed conifer forest in southern New Mexico, Krauch (1956) found repeatedly that rodents destroyed spot seedings unless the seed was protected. An Arizona study showed that, where grass was seeded shortly after germination of pine seeds, seedling survival dwindled almost to zero within 3 years (Jones 1967), presumably under conditions of severe dry season moisture stress induced by the grasses (Embry 1971). Frost heaving can also kill many seedlings (Schubert 1970).

Methods

This study was carried out on three small clearcut strips near one another at about 8,900 ft elevation in east-central Arizona on variable

easterly and northerly slopes. Normally covered with snow throughout the winter, the sites are presumably less subject to frost heaving than many. They were baited with sodium fluoroacetate (compound 1080) at three strategic times to reduce predation by rodents on seeds and seedlings.

The species selected for seeding were southwestern white pine (*Pinus strobiformis* Engelm.) and blue spruce (*Picea pungens* Engelm.). White pine roots deeply the first year, to about 8 inches. Blue spruce penetrates only 2-4 inches the first year. Seedlings of both species seem to tolerate full sunlight well.

Six hundred staked spots were sown, in 10 rows with 30 pairs of spots in each row. Within each pair of spots, one selected at random was protected from rodents by a 4-mesh hardware-cloth cone. The pairs of spots were also in pairs, one pair randomly assigned to spruce, the other to pine. Due to a logistics problem, however, only 120 blue spruce pairs, instead of 150, included a screened spot. Species comparisons include only those pine spots paired with similarly treated spruce spots.

Laboratory germination was 66 percent for the blue spruce and 52 percent for the white pine. To provide an average of three viable seeds in each seed spot, five seeds were placed in each spruce spot and six in each pine spot. That should have assured at least one good seed in almost every spot.

Each spot was loosened with a mattock before seeding, to prepare the seedbed and ascertain that the spot was not underlain by a stone or by organic debris buried during logging or slash piling. Seeds were then placed on the loosened surface and lightly pressed into the ground by foot.

Seeding was on June 27 and 28 and July 8 and 9, 1970. A heavy shower on June 23 was followed by several days of typical dry-season weather. On June 29, high humidities and cloudiness began, presaging the monsoon. Showers became frequent and substantial beginning July 8.

In 1970 all seed spots were examined for germination and mortality on July 28-29, September 8-9, October 9-10, and October 28. Rodent screens were removed on October 9-10 so they would not be pushed downhill by snow and possibly damage seedlings. They were not put back on. The second year, 1971, all spots were examined for additional germination and mortality on May 4-5, July 24, and October 15. In 1972, only those spots were examined that had surviving seedlings when last previously examined; the dates were May 14 and July 7.

In 1971 the areas were inadvertently seeded with grass by Forest personnel, and a few spots were destroyed by a bulldozer. Numerous unseasonable showers in May and June 1972 maintained good soil moisture, however, and therefore competition from grass did not seem serious at that time.

Field examinations were discontinued in July 1972 because few seedlings were still alive.

Germination data were analyzed statistically, but not mortality data. Mortality causes were not independent. For example, because more unscreened than screened seedlings were killed by predators the first summer, fewer were subsequently exposed to frost heaving. Also, assignment of cause was sometimes a matter of judgment and subject to error. Furthermore, the factors influencing those judgments were not entirely the same at different times or for different treatments. Thus, while it is informative to examine and consider mortality data, statements of statistical probability are not justified.

Germination

Germination was defined by the presence of a seedling or seedling stub aboveground; 852 pine and 549 spruce are known to have germinated. Of the spruce that germinated, 64 percent came up before July 28, 1970, although many additional seedlings (34 percent) came up between then and September 8. White pine was slower; many (37 percent) germinated by July 28, but most (61 percent) appeared between then and September 8. Very few germinated after September 8; an occasional seed of both species germinated in 1971. The percentage germinating after July 28 was lower on unscreened spots than on screened spots. This is probably because unscreened seeds that did not germinate promptly were exposed to predators longer and had a greater chance of being eaten.

Fifty-six percent of screened white pine seeds and 55 percent of screened blue spruce seeds germinated, figures roughly equaling results in the germination chamber. For unscreened spots, the figures were 38 and 27 percent, respectively, for pine and spruce. Ninety-three percent of screened and 85 percent of unscreened pine spots had at least one seed germinate on them. For spruce, the values were 88 and 62 percent. A few spots were buried by soil washing before germination could be checked. If they are left out of the calculations, 96 percent of screened pine spots and 93 percent of screened spruce spots had at least one seedling emerge.

The difference between the numbers of seeds germinating on screened and unscreened spots (fig. 1) was highly significant statistically. That is in line with the observation of opened seedcoats on or around a number of unscreened

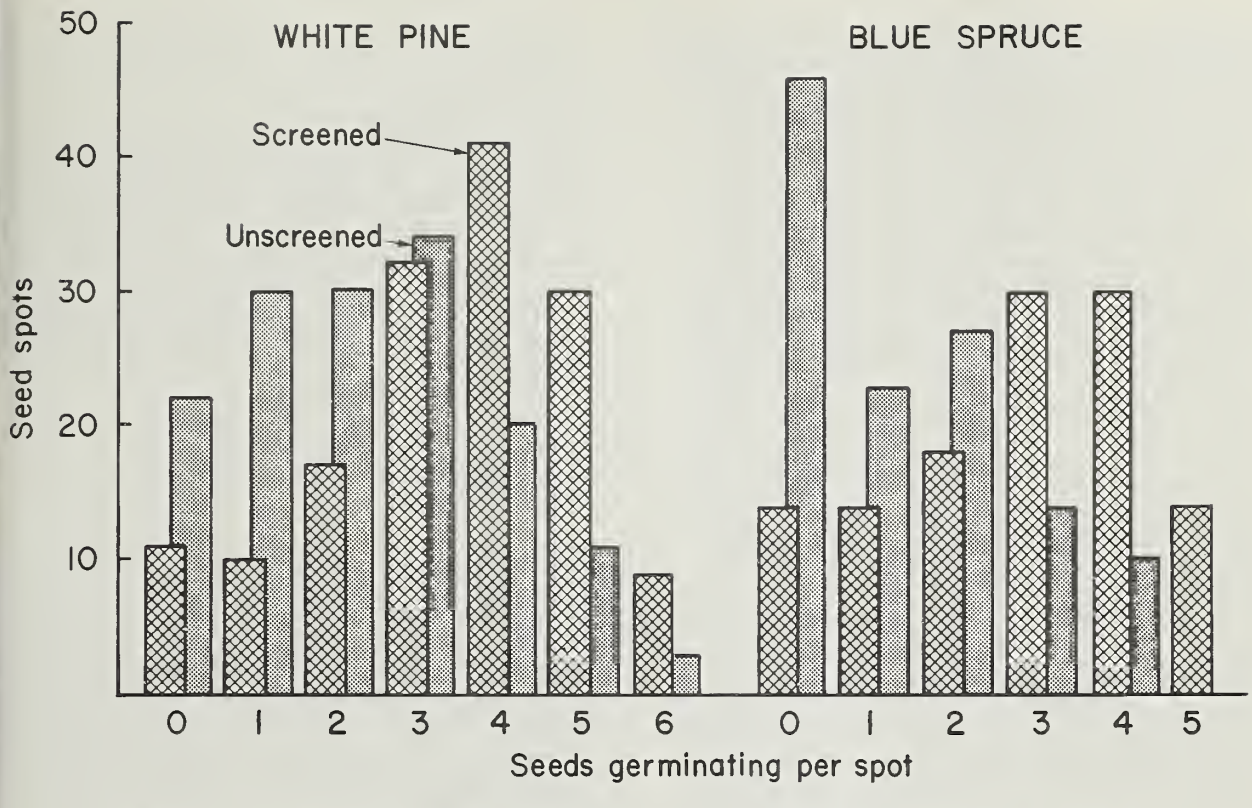


Figure 1.—Frequencies of different numbers of seed germinating on screened and unscreened spots.

spots. The difference between screened and unscreened spots was greater for spruce than for pine, suggesting that predators prefer seed of blue spruce to that of white pine. The species difference was not statistically significant, however.

Table 1.--Stocking on July 7, 1972, 2 years after seeds were sown

Species and treatment	Stocked spots		Total seedlings	
	Any live seedling	Vigorous seedling	Alive	Vigorous
	Percent		*Number*	
Spruce, screened (120 spots)	1	1	2	2
Spruce, unscreened (180 spots)	0	0	0	0
Pine, screened (150 spots)	21	7	72	20
Pine, unscreened (150 spots)	10	2	23	4

Mortality

Seedling mortality began immediately after germination. A number of seedlings were recorded as having emerged only on the basis of the tiny stubs left by rodents and perhaps other predators. Some damage suggested clipping by birds (Noble and Shepperd 1973). After 2 years only 97 seedlings remained, many of them in poor condition, out of the total known germination of 852 pine and 549 spruce (table 1). Of the 97 survivors, only 26 seemed vigorous.

Figure 2 shows what became of the rest. Because the columns represent percentages of seedlings, differences between columns are not influenced by the greater germination on screened spots.

Seedling Predation

Rodent reduction with compound 1080, although quite temporary, seems to have protected unscreened seedlings fairly well. Seedlings are most likely to be eaten during the first days and weeks after germination, when they are most succulent. Further, Douglas-fir tube

seedlings (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) were planted on one of the study blocks shortly after the seed spots were sown. Losses to rodents were moderate. On nearby areas untreated with 1080, all the tubelings were eaten.

Seedling predation on screened spots was less than half that on unscreened spots, but still was significant. Because predation did not stop entirely when stems became woody, some took place after the screens were removed. Some occurred earlier because elk, cattle, and deer dislodged a number of screens. A few screens were undermined by washing. Some seedlings were cut although their screens were in place, suggesting predation by insects. In the greenhouse, caterpillars occasionally eat the tops of young seedlings, and can do considerable damage in a few days. Cutworms were occasionally found by digging around wilted seedlings.

In an earlier study (Jones 1967), rodents tunneled under a number of screens to get to seed, but not to seedlings. There was almost no evidence of tunneling here.

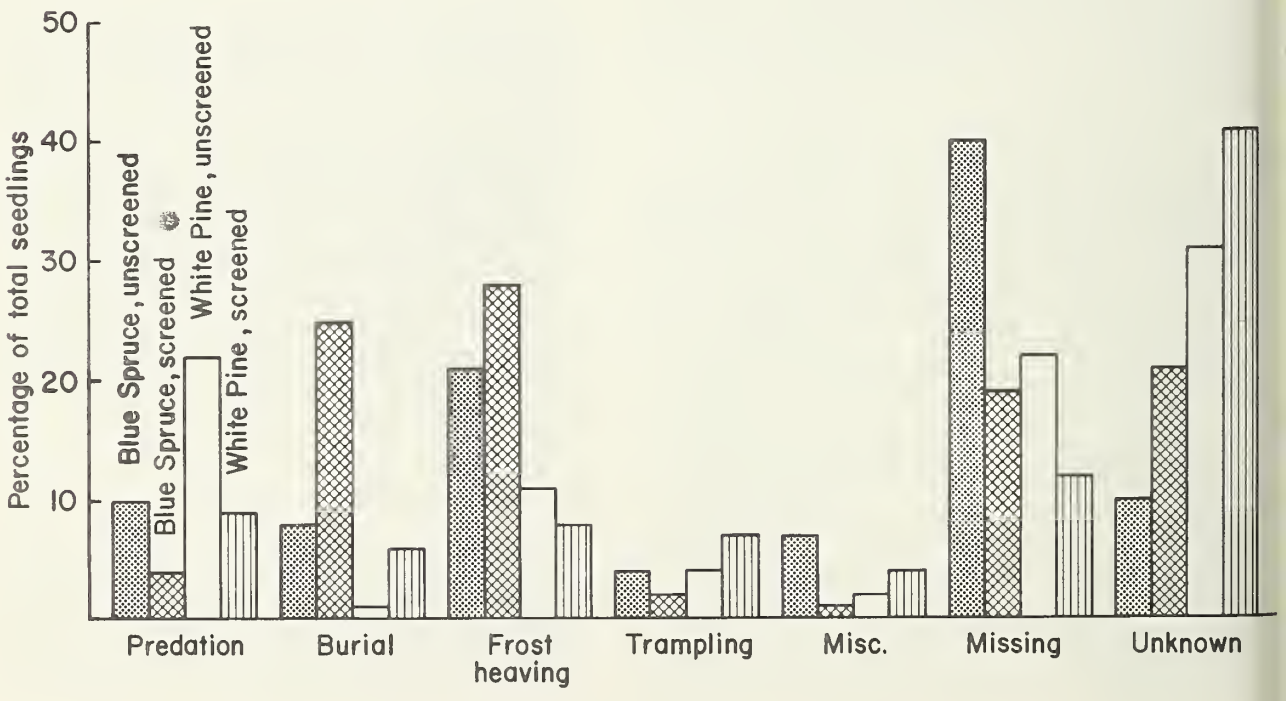
Occasional seedlings died during emergence when their cotyledons stuck in the ground and the hypocotyl broke. Recognizable evidence of this situation generally remains, but a few such seedlings may have been wrongly diagnosed as killed by predators.

A substantial number of seedlings in the Missing category probably were victims of rodents. That is especially true of spruce, whose tiny seedling stem leaves a stub that is difficult to see. Thus predation on spruce seedlings may in fact have approached or even exceeded predation on pine seedlings. Digging for evidence of predation commonly was not possible without disturbing seeds or other seedlings in the seed spot.

Buried Seedlings

Partial burial of seedlings by soil washing was common and usually did not seem harmful. Complete burial was a major source of death among spruce, whose seedlings are very small. Burial was common the first summer. It was most serious on screened spots, partly because screens tended to collect sediment, and partly because more seedlings survived predation on screened spots and were available for burial.

Figure 2.—Seedling mortality, by causes.



Frost Heaving

Frost heaving did not occur until seedling numbers had already been substantially reduced by predators and, in the case of spruce, by burial. Otherwise the importance of frost heaving would have been greater. On the other hand, snow cover was substantially subnormal during both winters. Frost heaving might possibly have been less had snow cover been normal.

The difference between screened and unscreened spots is probably due to chance. The screens had been removed before significant frost heaving occurred, so could have had little if any direct influence. Nor do the percentages surviving predation and burial, and available for frost heaving, seem to account for treatment differences.

Frost heaving seems to have killed considerably more spruce than pine, with its much larger root system. Many spruce were totally uprooted and lay on the surface. Some spruce listed as missing undoubtedly had frost heaved and subsequently washed downhill.

Pine seedlings whose deaths were ascribed to frost heaving commonly lay on the ground only partly uprooted, or even remained upright but considerably raised. Some pine seedlings survived, even though raised half an inch or more. Not infrequently, one pine seedling would be prone and largely uprooted, while others an inch or two away seemed unraised. Presumably some of the unraised seedlings had also undergone the kind of stress that had uprooted their neighbors. Some, perhaps many, of the pine listed as dead of unknown causes may have died from damage done when ground freezing and heaving put upward stress on the root collar of a firmly anchored seedling.

A few seedlings, broken off just below the surface, were listed as victims of frost heaving. This resembled cutworm damage, but occurred during the cold season. Others broken off may have been washed away and listed as missing.

Soil raised by needle frost seems to have buried a few seedlings. They were listed as killed by frost heaving rather than by burial.

Trampling

An impressive 187 spots out of 600 were disturbed by elk, cattle, or deer. They were either stepped on, slid on, or screens were kicked off. Numerous spots were disturbed more than once. Yet trampling was not a major cause of death of these flexible young seedlings. Most were simply stepped on and seemed to recover, although a few of these may have died later from the effects and been listed under **unknown**. More serious than being stepped on was scuffing and, on steeper slopes, being slid on. Such action was likely to break or at least partially uproot seedlings.

Elk, which were numerous and frequented the clearcuttings in spring, summer, and fall, caused most seed spot disturbance. Cattle were present for only about 3 months a year. Deer tracks were not numerous, and deer, of course, step more lightly.

Miscellaneous Identified Causes

Washing out was a significant minor cause of spruce deaths, but killed very few pine. Typically the seedling was not washed out entirely. Rodent screens seem to protect substantially against washing out.

A few pine hypocotyls broke during germination. More often a few cotyledons broke off during emergence. The latter did not seem to kill seedlings, although such damage may have weakened seedlings and contributed to later deaths by other causes.

Seedlings on several white pine spots were killed by a bulldozer, and on two by an off-road vehicle. No spruce were killed by these events because no spruce had survived there.

Missing

There were many unaccounted for seedling disappearances. Probably the biggest causes were predation and the washing away of frost-heaved seedlings. It is hard to think of other factors that would cause the disappearance of so many seedlings. Missing was the largest category for spruce, which was also the likeliest to heave entirely out of the ground and the hardest to find when cut by a predator. Although roots and stubs of many seedlings listed as missing might have been found by digging, such digging generally would have disturbed seeds or other seedlings.

Unknown

Deaths listed as **unknown** do not include missing seedlings. No meaningful interpretation can be made of difference between species and treatments in the **unknown** category.

When a seedling is found dead with no evidence of cause, it is tempting to ascribe death to moisture stress. With relatively little herbaceous competition, however, moisture conditions should have remained rather favorable below the upper 2 inches or so of soil throughout the dry season (Embry 1971). Considering rooting depths and previous experience, it is questionable that pine seedlings died from moisture stress unless their root systems had been damaged by insects, disease, or frost heaving (Jones 1967, 1971, 1972). Some or even many pine deaths tallied under **unknown** may have been caused by frost heaving that broke the inner bark of well-anchored seedlings, but that is speculation. Another possibility is disease.

Spruce, with its tiny root system, may be considerably more susceptible to drought killing in the absence of root injury, though it is not clear that such drying was, in fact, an important source of spruce deaths.

Other

In some regions, heat girdling and snow blight are often identified as important seedling killers. In this study, no lesions from heat girdling were found. Such absence may reflect in part the infrequency of examinations combined with the transient nature of the lesion after death. If heat girdling had been common, however, a number of cases would almost surely have been encountered with the cause still apparent. The scarcity of heat girdling was probably due to the northerly and easterly aspects, and to the wet soils and cloudy skies usual during the summer.

No seedlings were recognized as killed by snow blight.

Conclusions

Spot seeding provided a very low ratio of seedlings to seed, and of spots stocked to spots sown, after only 2 years. Success was poor despite favorable slope aspects, absence of heavy herbaceous competition, generally good cold air drainage, substantial rodent control, and high germination percentage.

Spot seeding does not look promising as a means of regenerating mixed conifer clearings in the Southwest, even if chemical control of rodents is permitted. Seedlings that escape one hazard are repeatedly exposed to others. Species with especially small seedlings are particularly poor candidates, but even species with relatively large seedlings seem unlikely to provide adequate stocking.

In contrast to spot seeding, broadcast seeding attempts to surmount obstacles by sowing so many seeds that even a small ratio of seedlings to seed will adequately restock the area. Furthermore, heavy broadcast seeding seems able to feed the predators without critically reducing the seed available for germination. Spreading a mixture of inviable oats to satiate the rodents has also been suggested. Further research on seeding mixed conifer clearings should examine broadcast seeding rather than spot seeding.

Meanwhile, to restock mixed conifer clearings promptly, the manager should plant, unless aspen sprouts abundantly and is acceptable.

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